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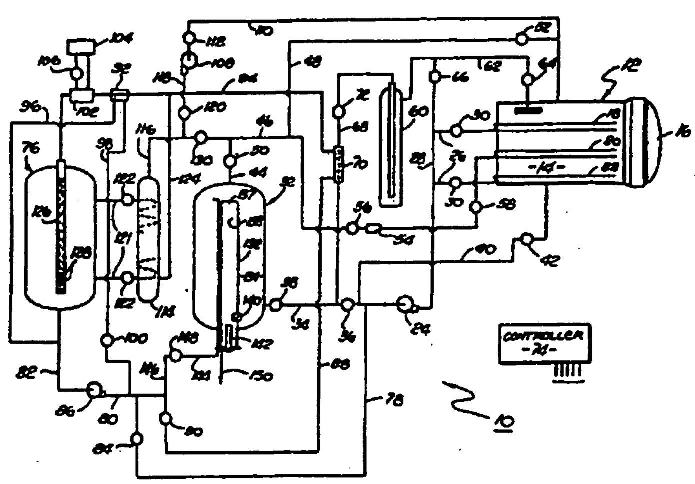
(54) Title: A SUPER-COOLED FLUID TEMPERATURE CONTROLLED CLEANING SYSTEM



(57) Abstract

A liquid gas based cleaning system (10) includes a cleaning vessel (12) that holds an item to be cleaned and is filled with a volume of liquid gas such as carbon dioxide. The liquid carbon dioxide is circulated through the cleaning vessel (12) to remove contaminants from the item. A secondary supply of super-cooled liquid gas is introduced to the cleaning vessel (12) to maintain the temperature of the liquid gas below a critical value. After the item is cleaned, the liquid gas is pumped to a single storage/still vessel (32) which both distills and stores the gas. Removing the liquid gas from the cleaning vessel (12) creates a residual vapor gas that is sparged in a bath of super-cooled liquid gas. The liquid gas within the cleaning vessel (12) is thus fully received for use in another cleaning cycle.

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A SUPER-COOLED FLUID TEMPERATURE CONTROLLED CLEANING SYSTEM

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a system for cleaning with a liquid gas.

2. DESCRIPTION OF RELATED ART

Conventional "dry" cleaning systems utilize aggressive solvent materials such as chlorofluorocarbon. It has been found that chlorofluorocarbons are harmful to the environment. There have been developed systems which utilize alternative cleaning substances such as liquefied carbon dioxide (CO_2). Liquefied carbon dioxide is environmentally inert and more economical than conventional cleaning solvents.

U.S. Patent Nos. 5,316,591; 5,339,844; 5,467,492 and 5,456,759 issued to Stanford and Chan, and assigned to Hughes Aircraft Company, disclose systems for cleaning with liquefied carbon dioxide. The Hughes system includes a cleaning vessel that is filled with liquid CO_2. The CO_2 is then agitated to remove contaminants from an item(s) placed within the vessel. After the item is cleaned, the liquid carbon dioxide is purged from the cleaning vessel. The purged CO_2 is typically stored within a pressure tank for use in another cleaning cycle. It has been found that the removal of liquid carbon dioxide from the cleaning vessel creates a residual vapor gas within the system. Because CO_2 is environmentally inert the gas is typically vented to the atmosphere. Venting the gas requires a periodic CO_2 recharge of the storage tank.

Recharging the storage tank with CO_2 increases the cost of operating and maintaining the system. It would therefore be desirable to provide a liquid gas based cleaning system that recycles the cleaning fluid without venting the gas.

One way of agitating the cleaning fluid is to circulate the liquid gas through the cleaning vessel with an external pump. Circulating the liquid gas generates energy which increases the temperature of the gas. It has been found that liquid gas such as carbon dioxide has a maximum temperature at which the gas no longer become aggressive. It is therefore critical to maintain the temperature of the liquid CO_2 below the critical temperature. Prior art systems utilize a heat exchanger to control the temperature of the liquid gas. Using a separate heat exchanger increases the size and cost of the system. It would therefore be desirable to provide a cleaning system that can control the liquid gas temperature without a large separate heat exchanger.

The $CO2$ purged from the cleaning vessel is typically distilled within a distillation vessel. The distilled CO_2 is then stored within a separate storage tank. Having two separate components increases the space and cost of providing the system. It would be desirable to provide a single component that both distilled and stored the purged liquid gas from the cleaning vessel.

SUMMARY OF THE INVENTION

The present invention is a liquid gas based cleaning system. The system includes a cleaning vessel that holds an item to be cleaned and is filled with a volume of liquid gas such as carbon dioxide. The liquid carbon dioxide is circulated through the cleaning vessel to remove contaminants from the item. A secondary

supply of super-cooled liquid gas is introduced to the cleaning vessel to maintain the temperature of the liquid gas below a critical value. After the item is cleaned, the liquid gas is pumped to a single storage/still vessel which both distills and stores the gas. Removing the liquid gas from the cleaning vessel creates a residual vapor gas that is sparged in a bath of super-cooled liquid gas. The liquid gas within the cleaning vessel is thus fully received for use in another cleaning cycle. The cleaning vessel may contain a cage that is rotated by the impingement of the circulating liquid gas on a cage blade to induce further agitation within the vessel. The cage may be connected to a quick disconnect base plate that allows various embodiments of cages to be readily attached to the vessel.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, wherein:

Figure 1 is a schematic of a cleaning system of the present invention;

Figure 2 is a schematic of the system showing a cleaning vessel being filled with a liquid gas;

Figure 3 is a schematic of the system showing the liquid gas being circulated through the cleaning vessel;

Figure 4 is a schematic of the system showing the liquid gas being pumped out of the cleaning vessel;

Figure 5 is schematic showing a pump assembly of the present invention;

Figure 6 is a side sectional view showing a basket assembly of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings more particularly by reference numbers, Figure 1 shows a cleaning system 10 of the present invention. The system 10 is typically utilized to clean an item with a liquefied gas. In the preferred embodiment, the gas is carbon dioxide (CO_2). Although carbon dioxide is described, it is to be understood that other gases such as nitrogen, nitrous oxide, sulfur hexafluoride and xenon may be used in the system 10. The system may clean with processes disclosed in U.S. Patent Nos. 5,316,591; 5,339,844; 5,467,492 and 5,456,759, which are hereby incorporated by reference.

The system 10 includes a cleaning vessel 12 which has a an inner chamber 14. The inner chamber 14 can be exposed by opening a door 16. Within the vessel 12 are a plurality of headers 18, 20 and 22 that discharge the liquid gas into the inner chamber 14. The inner chamber 14 is typically of sufficient size to contain a number of items such as a pile of clothing. Although clothing is described, it is to be understood that the cleaning system 10 may clean a variety of items.

Headers 18 and 22 are connected to a pump 24 by fluid lines 26 and 28, and valves 30. The pump 24 is connected to a storage/still vessel 32 by line 34 and valves 36 and 38. Line 34 is also connected to the inner chamber 14 by line 40 and valve 42. The storage/still 32 stores a volume of liquid gas that can be transferred to the cleaning vessel 12. Liquid carbon dioxide is typically stored in the vessel 32 at a pressure between 600-800 psi and at a temperature in the range of 60 °F. The storage/still 32 is connected to the cleaning vessel 12 by lines 44, 46 and 48, and valves 50 and 52. Line 46 is connected to a heater 54 and the header 20 by valves 56 and 58, respectively.

The cleaning vessel 12 is connected to a filter unit 60 by line 62 and valve 64. Line 62 is coupled to line 28 by valve 66. The filter unit 60 typically has a filter membrane that filters out particulates from the liquid gas. The filter 60 is connected to line 34 by line 68 which extends through a heat exchanger 70. The flow of the liquid gas through line 68 is controlled by valve 72. The valves, pump and other components of the system can all be controlled by a controller 74.

As shown in Figure 2, the inner chamber 14 can be filled by opening valves 36, 38, 42, 50 and 52 and allowing the highly pressurized liquid gas within the storage/still vessel 32 to flow into the cleaning vessel 12. As shown in Figure 3, when the inner chamber 14 is filled, the liquid gas can be circulated through the cleaning vessel 12 by closing valves 42 and 52, opening valves 30, 36, 64 and 72, and activating the pump 24. The liquid gas is discharged from the headers 18 and 22 into the inner chamber 14. From the inner chamber 14 the liquid gas flows through the filter 60, along line 68 and back into the pump 24.

The circulation of the liquid gas creates energy that will raise the temperature of the gas. It has been found that the aggressive cleaning characteristics of liquid carbon dioxide reduces when the temperature exceeds a critical temperature. The critical temperature varies depending upon the pressure and composition of the gas. It is therefore desirable to maintain the temperature of the liquid CO_2 below the critical temperature. The temperature can be controlled by introducing a super-cooled liquid gas into the circulating liquid during the cleaning process.

The super-cooled liquid can be stored within a cold storage tank 76. The super-cooled liquid gas is typically stored at a temperature between -20 and -30 °F, and a pressure of approximately 250 psi. The cold

storage tank 76 is connected to line 34 by lines 78, 80 and 82, valve 84, and pump 86. The pump 86 raises the pressure of the super-cooled liquid gas to a level which will allow the super-cooled liquid to flow into line 34 and the cleaning vessel 12. The quantity of super-cooled liquid introduced to line 34 is controlled by valve 84 and the controller 74. The system may have thermocouples (not shown) which provide temperature feedback to the controller 74. The controller 74 will vary the amount of super-cooled liquid gas introduced to line 34 to maintain the temperature of the liquid within the inner chamber 14 below the critical value.

The heat exchanger 70 is coupled to the super-cooled liquid gas by line 88 and valve 90. The temperature of the liquid gas within the cleaning vessel 12 is further controlled by valve 90 and the controller 74. The heat exchanger 70 is connected to a syphon unit 92 by line 94. The syphon unit 92 utilizes a venturi effect to pull super-cooled liquid gas from line 96 and 98 into the return gas flowing through line 94. The flow of liquid gas through line 98 is controlled by valve 100. The syphon unit 92 pre-cools the liquid gas from the heat exchanger 70. The liquid gas is super-cooled by heat exchanger 102. The heat exchanger 102 is coupled to a refrigeration unit 104 and a valve 106.

After the circulation cycle is completed, the liquid gas must be purged from the cleaning vessel 12 so that the item can be removed from the inner chamber 14. As shown in Figure 4, to purge the liquid gas, valves 30, 36 and 84 are closed and valves 42 and 66 are opened. The pump 24 pumps the liquid gas into the storage/still 32. The purging of liquid gas from the inner chamber 14 will create a residual vapor gas in the system. The vapor gas is drawn out of the inner chamber 14 by a compressor 108 that is connected to the cleaning vessel 12 by line 110 and valve 112. The compressor 108

is connected to a water separator 114 by lines 116, 46 and 118, and valve 120. The water separator 114 is also coupled to the cold storage tank 76 by lines 120 and valves 122. The water separator 114 condenses any moisture within the vaporized gas. The separator 114 typically has a trap to remove the condensed moisture.

The water separator 114 is connected to line 94 by line 124. The vaporized gas is further cooled by the syphon unit 92 and heat exchanger 102. The gas typically enters the cold tank 76 in a vaporized or two-phase liquid-vapor form. The vaporized gas is fed through a tube 126 which extends into the tank 76. The tube 126 has openings 128 which discharge the vaporized gas into the super-cooled liquid gas. The super-cooled liquid gas condenses the discharged vaporized gas in a process typically referred to as sparging.

Some of the vapor gas can be directed to line 46 and the heater 56 by opening valve 130. The heater 56 super heats the gas which is then directed into the inner chamber 14 through open valve 58 and header 20. The heated gas raises the temperature of the item, which may be particularly desirable if the item is clothing.

The pump 24 and compressor 108 pull the gas out of the cleaning vessel 12 until the inner chamber 14 reaches essentially atmospheric pressure. The compressor 108 and pump 24 are then de-activated and the valves 30, 38, 42, 52, 58 and 66 are closed The door 16 is then opened so that the item can be removed from the cleaning vessel 12.

The storage/still vessel 32 both distills and stores the liquid gas for use in another cleaning cycle. The vessel 32 preferably includes a tube 132 located within an inner cavity 134 of an outer tank 136. At the top of the tube 132 is an opening 136 that provides fluid communication between the inner cavity 134 and an inner chamber 138 of the tube 132. The bottom of the

tube 132 has a one-way control valve 140 that allows the liquid gas to flow from the inner cavity 134 to the inner chamber 138.

The vessel 32 has a heating element 142 which can heat and vaporize the liquid gas within the inner chamber 138 of the tube 132. The vessel 132 also has a discharge tube 144 that is connected to the output of the super-cooled pump 86 by line 146 and valve 148. The tube 144 discharges super-cooled liquid gas which condenses the gas vaporized within the inner chamber 138. The condensed gas falls into the inner cavity 134, which then forms a layer of distilled "clean" liquid, on top of a layer of undistilled "dirty" liquid.

The still 32 vaporizes the liquid gas within the tube 132, which causes liquid to flow from the inner cavity 134 to the inner chamber 138. The cycle is continued until the level of dirty liquid falls below the valve 140. The valve 140 is turned off and the remaining liquid within the tube 132 is evaporated. The heating element 142 heats the liquid gas below the boiling point of contaminants such as oil so that the contaminants remain at the bottom of the tube 132 after the distillation cycle. The vessel 32 has a vent trap 150 that allows the contaminants to be removed from the tube 132. The vessel 32 provides a single component which can both distill and store the liquid gas.

Figure 5 shows a preferred embodiment of a pump 24. The pump 24 includes an impeller 160 located within an impeller chamber 162. The chamber 162 has an inlet port 164 and an outlet port 164. The super-cooled liquid gas is typically introduced to the pump inlet 164 to reduce the probability of cavitation within the pump 24.

The impeller 160 is driven by a motor 166 that is located within a motor chamber 168. The impeller chamber 162 is separated from the motor chamber 168 by a seal 170. Because of the relatively high operating

pressures of the system some of the liquid gas will leak into the motor chamber 168. The aggressive cleaning characteristics of the liquid gas have a tendency to remove the lubricants of the motor 166 and reduce the life of the pump assembly. The motor chamber 168 may have a heat exchanger 172 that heats the liquid gas to a temperature above the critical temperature of the gas. The gas will not attack the lubricated components of the motor 166 at the elevated temperature. The gas is preferably heated to a vapor state to create a gas seal within the chamber 168. The heat exchanger 172 can also remove the heat generated by the motor 166 to maintain the motor temperature within an operating range.

Figure 6 shows a preferred embodiment of a basket assembly 180 of the cleaning vessel 12. The assembly includes a basket 182 that is coupled to a base plate 184 by bearings 186. The basket 182 has a blade(s) 188 located adjacent to the output nozzles of the headers. The circulating liquid gas impinges upon the blade 188 and rotates the basket 182 to further agitate the liquid gas and item within the inner chamber 14.

The base plate 184 is preferably coupled to the base 190 of the vessel 12 by a plurality of fasteners 192 so that the plate 184 can be readily removed from the cleaning vessel 12. In this manner, different types of basket assemblies can be incorporated into the cleaning vessel 12. For example, the rotating basket can be replaced with a stationary basket.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.

CLAIMS

What is claimed is:

1. A liquid gas cleaning system, comprising:

a cleaning vessel that contains a volume of liquid gas;

a removal assembly that removes the liquid gas from said cleaning vessel, wherein the removal of the liquid gas creates a residual vapor gas; and,

a cold storage tank that is filled with a liquid gas, said cold storage tank having a tube that is connected to said cleaning assembly and which allows the residual vapor gas to sparge into the liquid gas within said cold storage tank.

2. The system as recited in claim 1, wherein said removal assembly includes a pump that pumps the liquid gas to a storage/still vessel which distills and stores the liquid gas.

3. The system as recited in claim 2, wherein said storage/still vessel includes, a primary vessel that has an inner cavity which contains the liquid gas, a secondary vessel located within said inner cavity of said primary vessel, said secondary vessel having an opening that provides fluid communication between said inner cavity of said primary vessel and an inner chamber of said secondary vessel, a control valve that controls a flow of the liquid gas from said inner cavity of said primary vessel to said inner chamber of said secondary vessel, and a heating element that is located within said secondary vessel to heat and vaporize the liquid gas within said inner chamber, wherein the vaporized gas flows through said secondary vessel opening and into said inner cavity of said primary vessel.

4. The system as recited in claim 3, wherein said storage/still vessel includes a port that is connected to said cold storage tank such that a volume of liquid gas from said cold storage tank is discharged into said inner cavity to condense the vaporized gas.

5. The system as recited in claim 4, wherein said secondary vessel has a trap.

6. The system as recited in claim 1, further comprising a valve that allows a volume of liquid gas to flow into said cleaning vessel to control a temperature of the liquid gas within said cleaning vessel.

7. The system as recited in claim 6, wherein said removal assembly includes a pump that pumps the liquid gas to a storage/still vessel which distills and stores the liquid gas, wherein said discharge valve introduces the liquid gas from said cold storage tank to an inlet port of said pump.

8. The system as recited in claim 7, wherein said pump includes a motor located within a motor chamber that contains a temperature control device that maintains a temperature of a volume of gas within said motor chamber above a critical temperature.

9. The system as recited in claim 1, wherein said cleaning vessel includes a basket that is coupled to a base plate.

10. The system as recited in claim 9, wherein a flow of the liquid gas impinges a blade of said basket to rotate said basket within said cleaning vessel.

11. The system as recited in claim 1, wherein said removal assembly introduces a superheated vapor gas into said cleaning system to heat said cleaning vessel.

12. The system as recited in claim 1, wherein the gas is carbon dioxide and a temperature of the liquid carbon dioxide in said cold storage tank is below -20 °F.

13. A liquid gas cleaning system, comprising:

a cleaning vessel that contains a volume of liquid gas;

a pump that is connected to said cleaning vessel to circulate the liquid gas through said cleaning vessel;

a cold storage tank that is filled with a liquid gas; and,

a valve that controls a flow of the liquid gas from said cold storage tank to said cleaning vessel to control a temperature of the liquid gas within said cleaning vessel.

14. The system as recited in claim 13, further comprising a storage/still vessel that is connected to said pump and which distills and stores the liquid gas.

15. The system as recited in claim 14, wherein said storage/still vessel includes, a primary vessel that has an inner cavity which contains the liquid gas, a secondary vessel located within said inner cavity of said primary vessel, said secondary vessel having an opening that provides fluid communication between said inner cavity of said primary vessel and an inner chamber of said secondary vessel, a control valve that controls a flow of the liquid gas from said inner cavity of said primary vessel to said inner chamber of said secondary vessel, and a heating element that is located within

said secondary vessel to heat and vaporize the liquid gas within said inner chamber, wherein the vaporized gas flows through said secondary vessel opening and into said inner cavity of said primary vessel.

16. The system as recited in claim 15, wherein said storage/still vessel includes a port that is connected to said cold storage tank such that a volume of liquid gas from said cold storage tank is discharged into said inner cavity to condense the vaporized gas.

17. The system as recited in claim 16, wherein said primary vessel has a trap.

18. The system as recited in claim 13, wherein said valve discharges the liquid gas to an inlet port of said pump.

19. The system as recited in claim 13, wherein said pump includes a motor located within a motor chamber that contains a temperature control device that maintains a temperature of a volume of gas within said motor chamber above a critical temperature.

20. The system as recited in claim 13, wherein said cleaning vessel includes a basket that is coupled to a base plate.

21. The system as recited in claim 20, wherein a flow of the liquid gas impinges a blade of said basket to rotate said basket within said cleaning vessel.

22. The system as recited in claim 15, further comprising a heater that heats the vaporized gas within said storage/still vessel to a superheated vapor gas that is provided to said cleaning vessel.

23. The system as recited in claim 13, wherein the gas is carbon dioxide and a temperature of the liquid carbon dioxide in said cold storage tank is below -20 °F.

24. A method of cleaning an item with a liquid gas, comprising the steps of:

a) placing an item into a cleaning vessel;

b) introducing a liquid gas to said cleaning vessel;

c) agitating the liquid gas to clean the item;

d) pumping the liquid gas out of the cleaning vessel, wherein the removal of the liquid gas creates a residual vapor gas; and,

e) sparging the vapor gas within a tank of liquid gas.

25. The method as recited in claim 24, further comprising the step of introducing a volume of liquid gas to said cleaning vessel to control a temperature of the liquid gas within said cleaning vessel.

26. The method as recited in claim 24, further comprising the step of distilling the liquid gas that is removed from said cleaning vessel.

27. A method of cleaning an item with a liquid gas, comprising the steps of:

a) placing an item into a cleaning vessel;

b) introducing a liquid gas to said cleaning vessel;

c) agitating the liquid gas to clean the item; and,

e) pumping a volume of liquid gas into said cleaning vessel to control a temperature of the liquid gas within said cleaning vessel.

28. The method as recited in claim 27, further comprising the step of pumping the liquid gas out of said cleaning vessel and distilling the removed liquid gas.

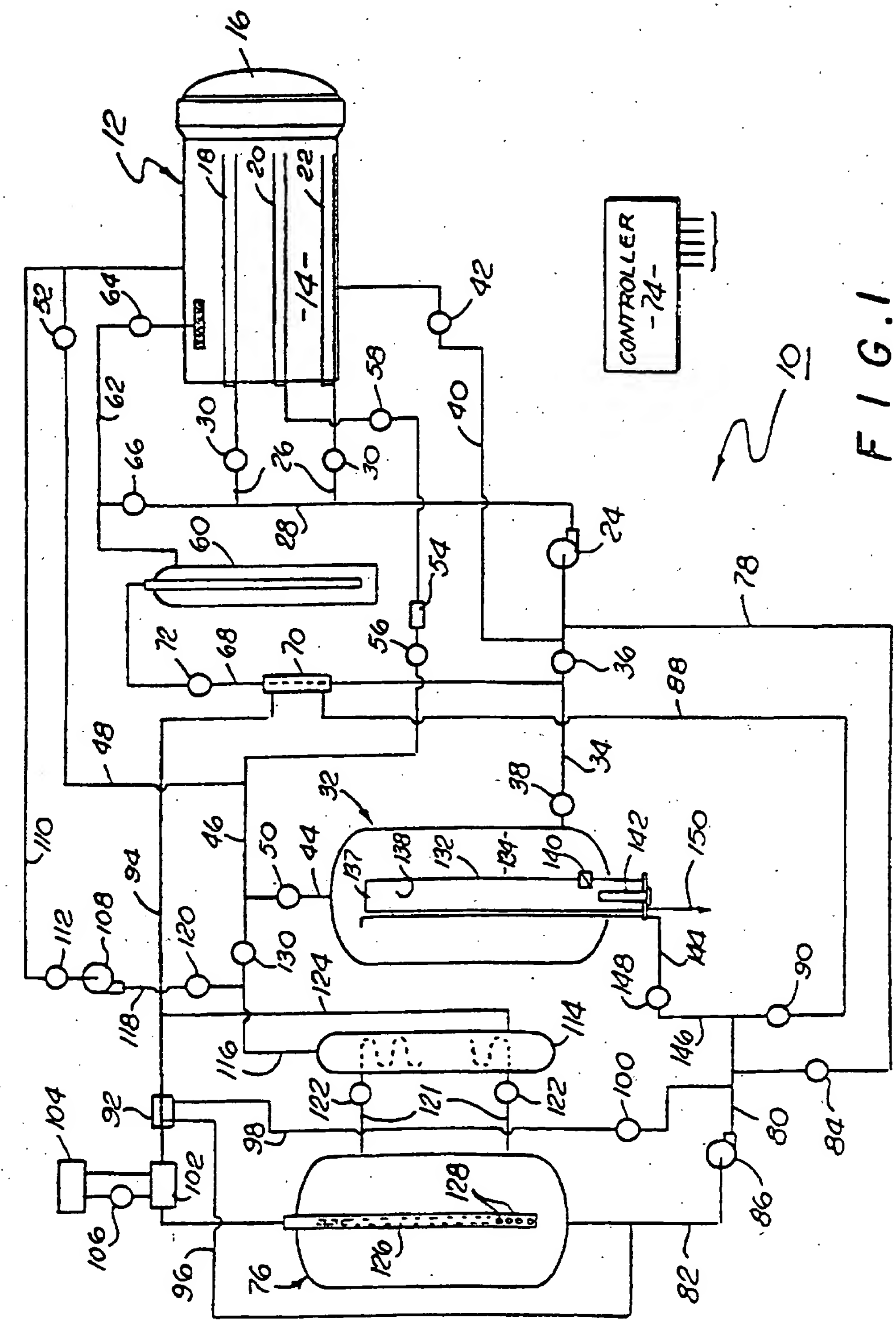

FIG. 1

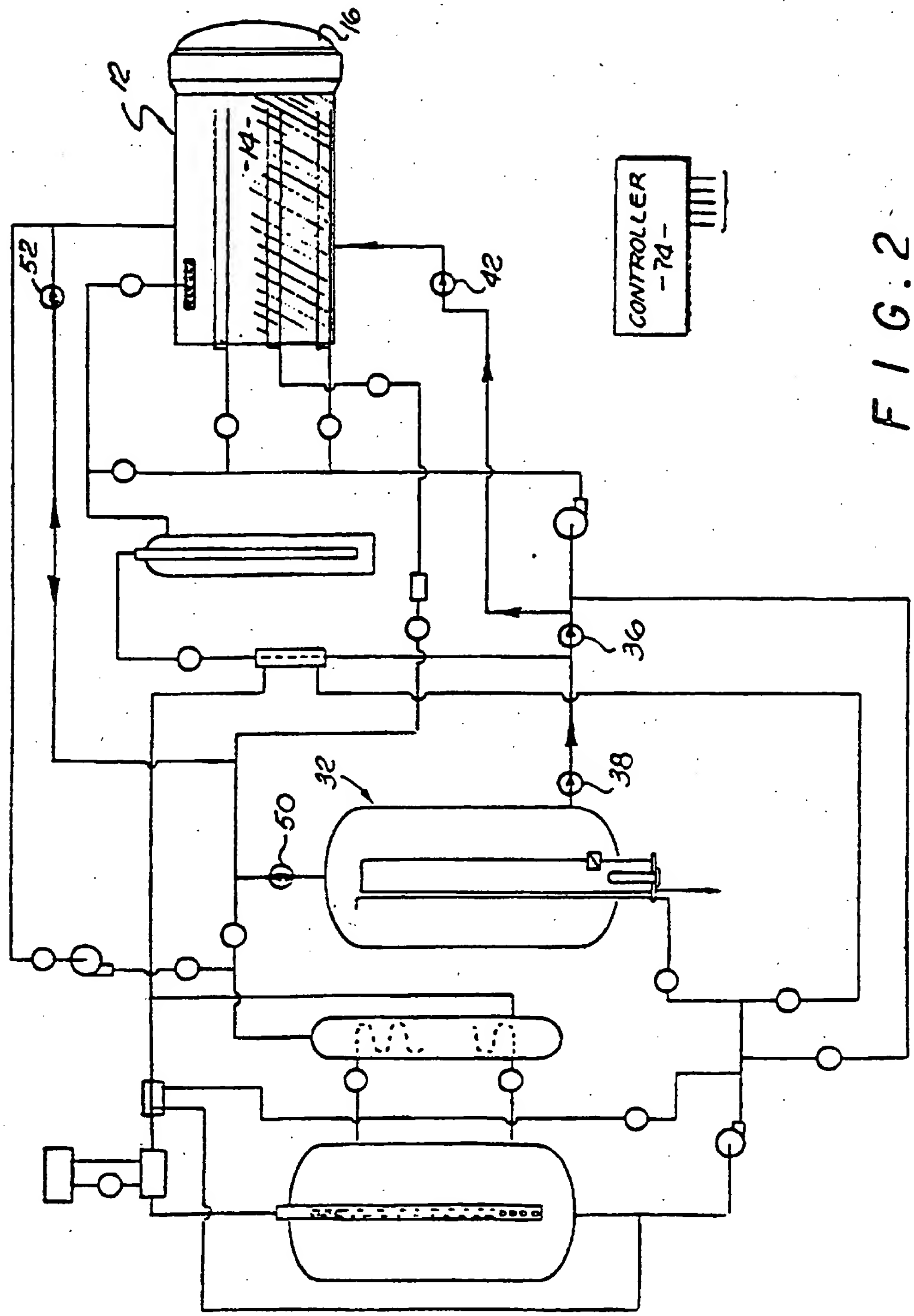

FIG. 2

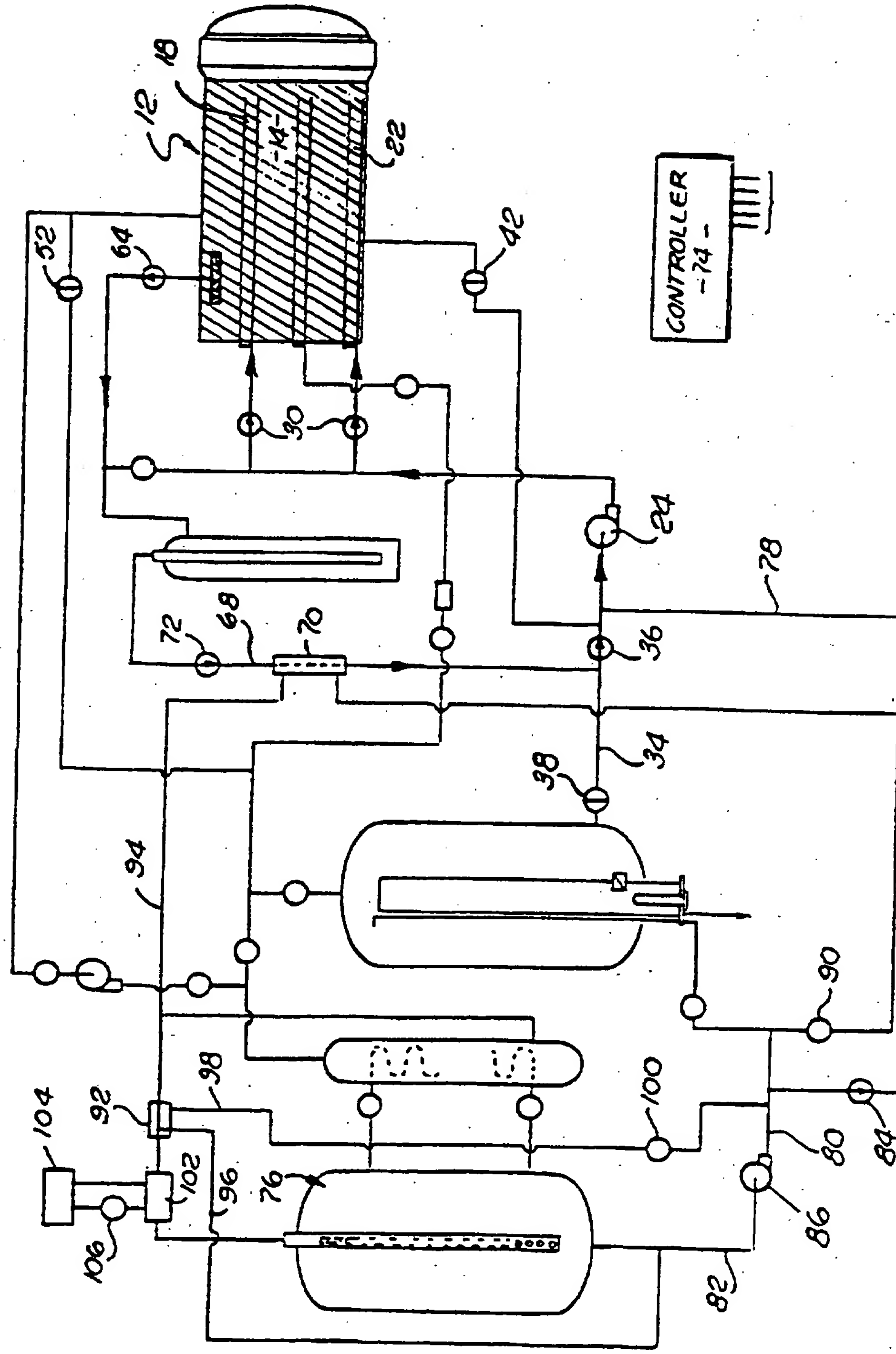
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FIG. 3

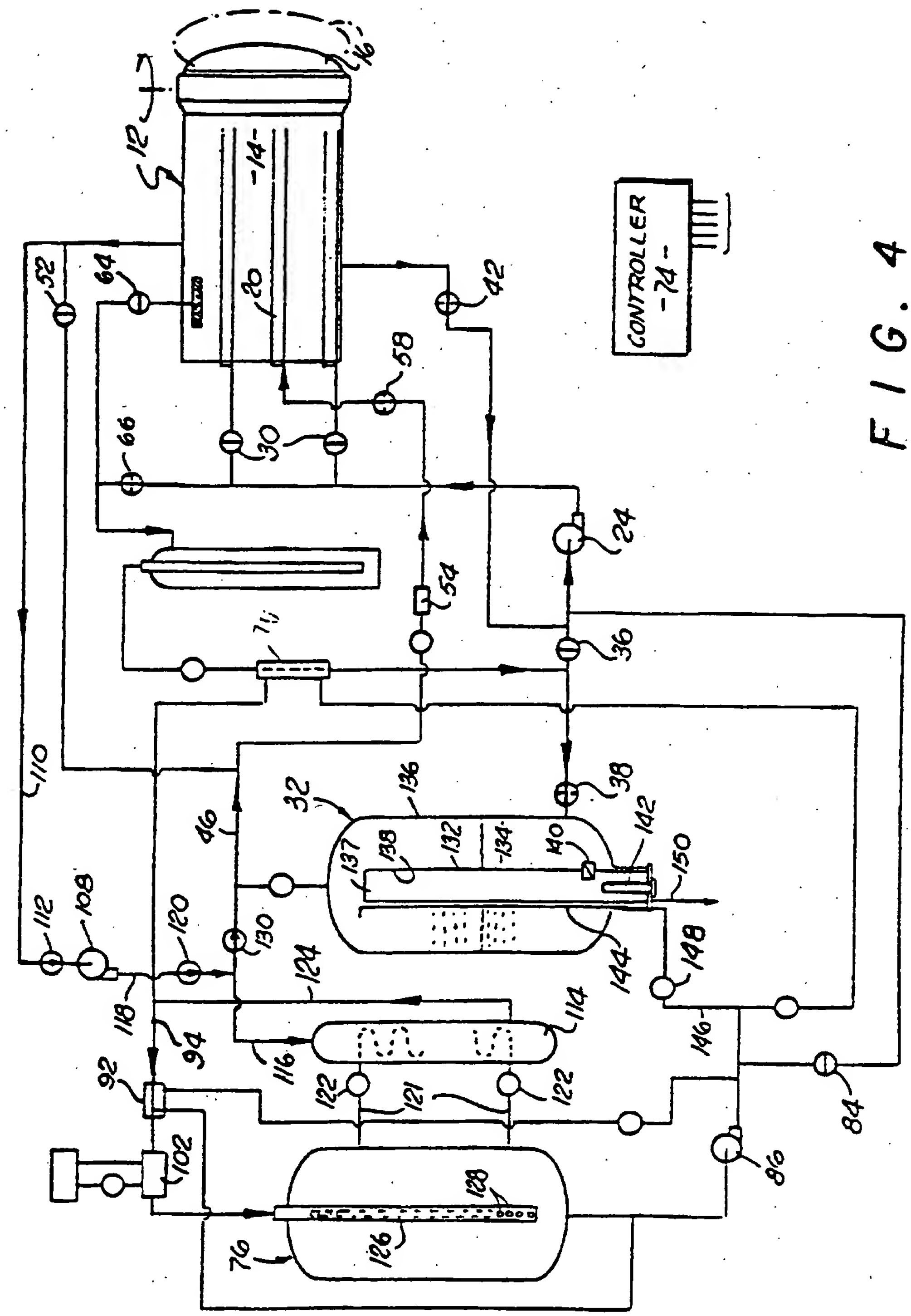
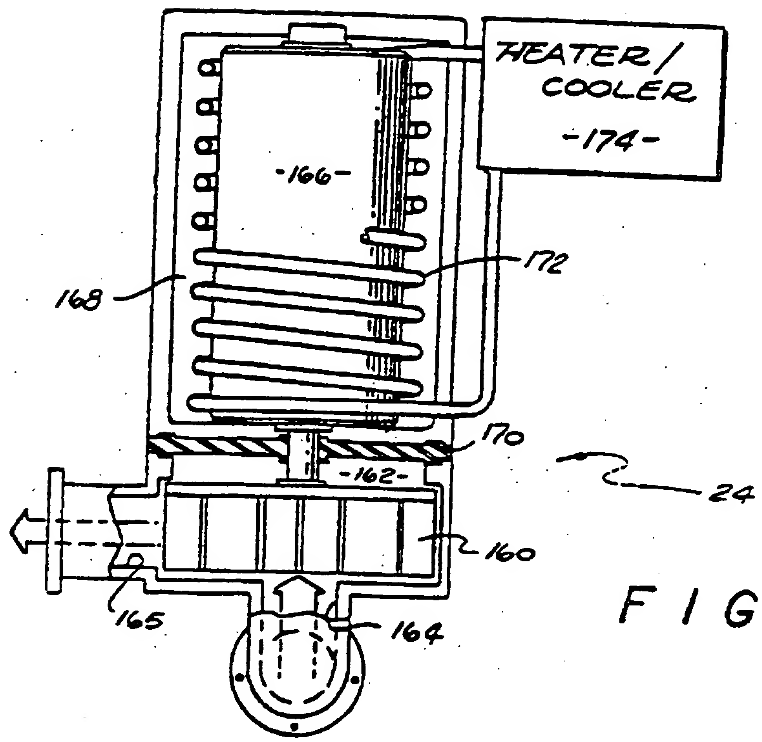


FIG. 4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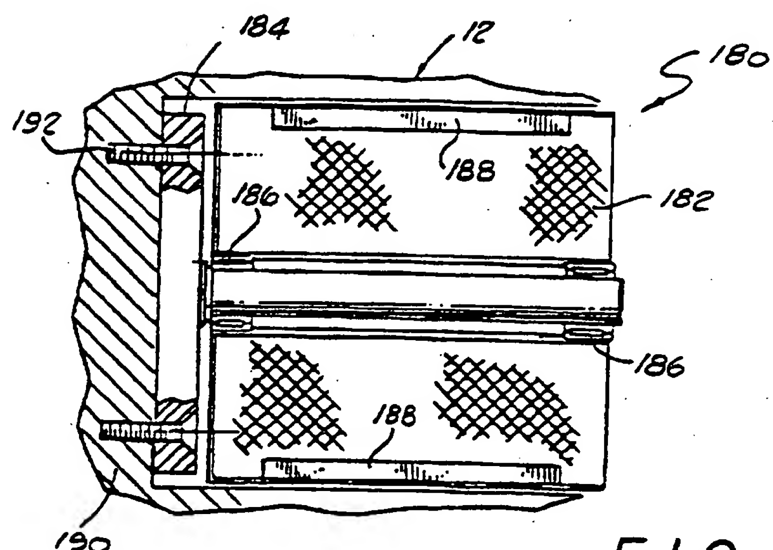
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F I G. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03675

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :D06F 21/04, 43/08
US CL :8/158;68/18R,18C
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 8/158;159; 68/18R,18C,148,151,183; 134/105,107,108,109,138,147

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 4,895,176 A (OHTSUKA ET AL) 23 JANUARY 1990, SEE ENTIRE DOCUMENT.	1,6,12 ---------- 9,10,14
Y	US 5,368,171 A (JACKSON) 29 NOVEMBER 1994, SEE COLUMN 7, LINES 55-65.	9
Y	US 5,482,064 A (GODDARD) 09 JANUARY 1996, SEE COLUMN 3, LINES 62-66.	10
X -- Y	US 5,467,492 A (CHAO ET AL) 21 NOVEMBER 1995, SEE ENTIRE DOCUMENT.	13,20,22, 23,27,28 ---------- 14,21

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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21 APRIL 1997

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2,816,426 A (KURLANCHEEK) 17 DECEMBER 1957, SEE COLUMN 3, LINES 32-35.	21